SOLAR PROBE

US-Russian Joint Mission

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We propose a Joint US-Russian Solar Probe Mission as a means to make the mission cost effective for both parties, while maximizing the science return of the mission. It is hoped by doing this we will be able to re-instate the Solar Probe Mission in NASA's present budget profile. This will be achieved by Russia providing the launch vehicle, Solar Electric Propulsion Module (SEP) and the RTG for the spacecraft. The US would provide the spacecraft, spacecraft tracking and mission operations.

The fundamental questions to be addressed by the Solar Probe Mission are the following: 1. How is the corona heated? 2. How are fast and slow winds generated? 3. What is the detailed magnetic and plasma coronal structure, radially and from pole to pole? 4. What is the origin of solar energetic particles? 5. What are the roles of waves, turbulence, microflares, subphotospheric flows, and nonthermal particles in all the above? Why are these questions so important? It is safe to say that Solar Probe will bring a Copernican-style revolution to our understanding of the solar wind and, by extrapolation, to a large class of stellar winds and thus of major astrophysical importance. Our Sun is the only star that is close enough that we can probe *in situ* the heating of the corona and the acceleration of the solar wind and thus provide important information about the mechanisms heating the corona of stars and the acceleration mechanisms of stellar winds. The solar wind engulfs the Solar System and carves out the region called the heliosphere which extends well beyond the orbits of the planets and protects the Earth from cosmic rays. The solar corona is one of the last unexplored regions of the solar system and one of the most important to understand in terms of Sun-Earth Connection. The science objectives of the mission are the answers to the questions noted above. It is also important to probe the solar corona and acceleration region of the solar wind during both solar minimum and solar maximum conditions.

The measurement strategies are to provide state of the art *in situ* measurements of plasma distribution functions, energetic particle fluxes, magnetic fields, and electric and magnetic components of plasma waves. Measurements of the plasma distribution functions will require a nadir viewing plasma spectrometer and oblique viewing plasma spectrometer in order to get true fast 3D plasma measurements. We also need remote sensing instruments of the solar disk using magnetograph/Doppler instrument and high spatial resolution EUV/X-ray imaging capabilities. A coronal all-sky imaging instrument will provide 3D tomographic mapping of the solar corona and provide a global perspective for the *in situ* measurements. An Ultra Fast Plasma Instrument (UFPA) of ions with 50 msec time resolution is needed to provide synchronized plasma and wave measurements to provide important information about coronal heating and structure.

The mission profile, which is shown as an example and can be changed, has a proposed launch in 22/06/2010, a 1st Electric Propulsion Logistics Module (EPLM) activation after launch for about 4 months, 2nd EPLM activation ~ 2 months at about 2 AU, 3rd EPLM activation for ~ 3 months followed by an Earth gravity assist at 29/08/2012 and then a cruise phase to Jupiter with encounter at 10/12/2013 when the spacecraft is thrown into the Sun with polar orbit and perihelion at 6 Rs 04/04/2016 with the Earth 90° from orbit plane for real-time tracking and data acquisition with data rates ~ 50 kbps. There will then be a second encounter several years later around solar maximum. The technology issues concern the high temperatures that must be tolerated by the spacecraft heat shield and plasma instrument nadir viewing feature which must tolerate temperatures ~ 2000°K, while keeping the spacecraft bus at around room temperature. Similar thermal issues must be tolerated by the remote sensing instruments.

At this stage we describe in more detail the science objectives and why Solar Probe is essential for their determination. For the last 30 years numerous mechanisms have been proposed for the heating of the corona and acceleration of the solar wind but both processes still remain illusive. The Ulysses observations clearly show the presence of high speed streams which invalidates the original thermal wind model proposed by Parker (1963). Additional energy sources are needed. Proposed mechanisms include high or low frequency wave heating and acceleration, impulsive heating, and/or injection of reconnection events (microflares, jets), and velocity filtration of highly non-Maxwellian portions of the plasma. Solar Probe is the only mission which has the greatest potential for discriminating between these various mechanisms because of its nearness to the Sun and once and for all have a clear understanding of the mechanisms heating the corona and accelerating the solar wind. It will also allow us to identify the origins of fast and slow solar wind. This will be done by combining *in situ* measurements (bulk plasma and magnetic field properties such as heat flux, beams of energetic particles, composition, magneto-hydrodynamic waves and plasma waves that extend beyond 4 Rs) and remote sensing observations of the photosphere, chromosphere and corona. Remote-sensing observations will determine the character of magnetic activity and whether the released energy is sufficient to supply the corona. The coronagraph observations will provide a 3D image of the corona and put the *in situ* observations within the global properties of the corona. Forms of energy generated by network events would leave different signatures at Solar Probe: direct heating would be seen in the electron heat flux; jets would produce shocks and energetic particles; bi-directional beams would indicate closed field lines; high frequency MHD waves would tend to dissipate at lower heights but indicate high speed flows beyond 4 Rs; longer period MHD waves would not dissipate until greater heights; and velocity filtration would leave a non-Maxwellian ion and electron distribution function. Jets, micro-flares and nano-flares would be seen by both the plasma instrument and energetic particle instrument and their occurance rate would tell how important they were in heating the corona. Jets can produce shocks and since jet speeds have been observed as high as 1000 km/s, the need for nadir viewing is essential. Solar Probe will detect the shocks and analyze resulting shock heating, acceleration and energetic particles. Flare activity, especially around solar maximum, would emit neutrons and γ-rays that could be detected by Solar Probe. Here, their occurance rate would be important with regard to energetic particle acceleration and their importance for heating the corona.

We encourage the continued research and development for the Solar Probe mission with regard to the spacecraft design, nadir viewing, energetic particle detection and plasma wave measurements. The same can be said for remote observation instrumentation. This will increase the TRL level of the mission and increase the probability of success in a harsh environment. The greatest emphasis should be on spacecraft design and nadir viewing since both must deal with high temperature technologies. Finally, by having a Joint US-Russia Mission one can make Solar Probe a more cost effective mission with a high science and technological pay off. A successful Solar Probe Mission will make the exploration of the inner heliosphere routine with a high TRL rating. We also want to encourage the development of new propulsion systems to allow immediate access to the inner heliosphere.